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OBSERVATIONS

ON

THE FUNCTIONS

OF

THE NERVOUS SYSTEM.

BY

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XXI. *Some observations on the functions of the nervous system, and the relation which they bear to the other vital functions.* *By* Alexander Philip Wilson Philip, *M.D. F.R.S. L. & E.*

Read April 2, 1829.

THE experiments relating to the function of digestion detailed or referred to in a paper which I lately had the honour to present to the Society, appear to throw light on the function of the ganglionic nerves, which hold a higher place in the animal economy than those either of sensation merely or voluntary power, being as essentially a vital organ as the heart or lungs, as will more fully appear, I think, from the review of facts which I now beg leave to submit to the Society.

For the last fifteen years I have been engaged in an experimental inquiry relating to the laws of the vital functions; and have from time to time laid the results before the Royal Society in six papers, which the Society has done me the honour to publish. All the experiments on which the statements are founded, having been made in the presence of competent witnesses, the rule from which I never deviated, has been to repeat each experiment till no doubt respecting the result remained in the mind of any one present; and it is satisfactory to me to be enabled to state, that, although many of these experiments have been repeated by the physiologists both of this country and the continent, they have in no instance been found inaccurate. I have always abstained from troubling the Society till I had some new facts to state, which appeared to me to deserve its attention; and I have confined myself to the simple statement of the facts and the means by which they were ascertained.

The present paper is offered to the Society on a different principle. It contains no new fact, but a review of what appears to me the necessary inferences from the various facts which I have had the honour to lay before it; and when the Society considers that the value of facts depends on the inferences they afford, and that the inquirer, both from his more perfect knowledge of the cir-

cumstances, and from his mind having been more particularly directed to the subject, is in several respects better fitted than others for reviewing the inferences, he hopes the following observations will not be unacceptable; especially as they are such as would naturally have made part of my former papers, had it not appeared to me better to confine myself to a simple statement of the facts, till the whole had been laid before the Society.

The present paper is offered to it for the purpose of supplying what may be regarded as a defect in those papers, and also as the conclusion of the Inquiry in which I have been so long engaged. I am fully sensible of the vast extent of the subject, and that it is only the great outline which I have attempted to trace. If this has been accurately laid down, my object has been accomplished.

The nerves may be divided into two classes, those which proceed directly from the brain and spinal marrow to the parts to which they convey the influence of these organs; and those which enter such ganglions as receive nerves proceeding from different parts of the brain and spinal marrow, whether these nerves have or have not protuberances belonging to themselves which have also been termed ganglions, but which receive only the different fibres that belong to the particular nerve to which they are attached, and from the circumstances in which they are placed, must have a different or at least a more confined relation to other parts of the nervous system. To the former, therefore, I shall for the sake of distinction, and to avoid circumlocution, confine the term ganglion.

I beg leave to lay before the Society the following extract from lectures delivered by Mr. Brodie before the College of Surgeons, and which have not yet been published, in which this accurate anatomist and physiologist has given the sum of our knowledge respecting the structure of the ganglions. "Those bodies which are found in certain nerves which appear to be formed by an enlargement of the nervous substance, and which are denominated ganglia, are of a complicated structure. Into ganglia the nervous fibres may be traced, and from these ganglia the nervous fibres again emerge. Scarpa has paid much attention to the fabric of the ganglia, and he gives the following history of it. He says that the fasciculi of nervous filaments which enter a ganglion are separated and divided from each other, and that they are combined anew. A nervous fasciculus entering a ganglion divides into smaller

fasciculi. These divide again, and cross and intersect each other at various angles. Then the divided fasciculi become again united, and as at first they divided into smaller and smaller fibres; so when they begin to unite they form gradually larger and larger bundles. At last the nerve which entered a ganglion emerges from it with its fibres collected into one or more fasciculi. Sometimes several nerves enter a ganglion, in which case they are all blended together, forming a complicated net-work, in which it is impossible to determine what belongs to one nerve and what belongs to another nerve. Every fasciculus or filament which enters a ganglion passes through it. There is no appearance of any one terminating in it."

"If we unravel the texture of a ganglion, we find that each nervous fibre retains its own peculiar neurilema; but besides this, the spaces left between the intersection of the fibres are filled up with a peculiar soft substance of a grayish or yellowish colour. With the nature of this substance we are unacquainted. Some have considered it as corresponding to the cineritious substance of the brain and spinal marrow; but SCARPA is disposed to regard it as a soft cellular substance, filled with a grayish and mucilaginous matter in emaciated subjects, and with a yellowish oily matter in those that are fat."

Such then is the structure of the ganglions as far as it is known; and as, for the reason just mentioned, I shall confine the term to those ganglions which receive nerves proceeding from different parts of the nervous system; the term ganglionic nerve I shall confine to those nerves which either enter or proceed from such ganglions, without adverting to their having or not having protuberances resembling ganglions belonging to themselves; although it is probable that a more perfect knowledge of the nervous system will point out this circumstance as a proper basis for a subdivision. It is necessary to keep this explanation in view, because neither the term ganglion nor ganglionic nerve has been employed with much precision.

Physiology has been greatly indebted to Mr. BELL for his important discovery of the different properties of the two sets of nerves which unite in forming each of the spinal nerves. It appears from his experiments, which have been confirmed by those of MAJENDIE, that the one set are nerves of sensation, the other of motion; a circumstance which explains many of the phenomena of disease, which have suggested the probability of these functions being

exercised by different nerves bound up in the same envelope. Dr. Parry in his treatise on the pulse for example, relates a case where feeling alone was lost in one arm, and voluntary power alone in the other. But these are not the only nor indeed the most important functions of the spinal nerves. All of them contribute to the formation of the ganglionic system, on which the life of the animal, as will appear from many facts I am about to state, immediately depends.

It is evident from what has been said, that the ganglions and plexuses resemble each other in their nature; and as the nerves which terminate in them come from all the most distant parts of the nervous system, some from the brain, and some from the lower extremity, and all intermediate parts of the spinal marrow, we cannot help supposing, that there is some design in thus uniting nerves which arise from so many different parts of these organs. One of the most striking differences between the ganglionic nerves, and those proceeding directly from the brain and spinal marrow, is that even independently of the ganglions and plexuses, the former every where more freely anastomose, if I may borrow a term from the sanguiferous system; while the latter proceed in a more direct course, being less connected with each other in their progress to the parts on which they bestow sensation and voluntary power; still further demonstrating the care with which nature blends the power of the ganglionic nerves.

What purpose is served by this perpetual intertwining of these nerves? It is impossible for a moment to conceive that it is without an object. This question is most likely to be answered by inquiring into the nature and functions of the parts supplied by this class of nerves; those parts are the vital organs, the thoracic and abdominal viscera, and the vessels even, as we shall find by experiment where the parts are too minute to be made the subject of dissection, to their smallest ramifications.

It would appear from this arrangement, that, although to other parts the influence of only one part of the brain or spinal marrow is sent, the vital organs receive that of every part of them; and this inference has been confirmed by numerous experiments too simple to admit of our being deceived, which I made many years ago, and the results of which were laid before the Royal Society, and published in the Philosophical Transactions of 1815, and which

are more fully detailed in my treatise on the Vital Functions. From them it appears that although the muscles of voluntary motion obey a stimulus applied to no part of the brain and spinal marrow but that from which their nerves take their origin; the heart is influenced by stimuli applied to every part of these organs, from the very uppermost surface of the brain and cerebellum to the lowest portion of the spinal marrow. The same was found to be the case with the blood-vessels to their minutest ramifications. Even the extremities of the arteries and veins, where they unite to complete the circulation, it was found by the aid of the microscope, could be influenced, nay even deprived of power by agents whose operation was confined either to the brain or spinal marrow.

In some animals even of warm blood, as appears from experiments related in my treatise on the Vital Functions, the motion of the blood in the capillaries may be observed for an hour or even two hours after death, provided neither great and sudden injury to the nervous system, nor great loss of blood be occasioned by the mode of death; that is long after the heart has ceased to beat. The continued action of the capillaries appears from what is said in that treatise, to be the cause of the large arteries being found empty some hours after death.

It has also been shown by experiments detailed in the same treatise, an account of some of which has appeared in the Philosophical Transactions, that the stomach and lungs are in like manner under the influence of both the brain and spinal marrow.

The partial connection with the nervous system of the organs supplied by the cerebral and spinal nerves, and the universal connection with that system of those supplied by the ganglionic nerves, explain many of the phenomena, both of health and disease. Why are affections of the stomach and other vital organs felt instantly through every part of the frame, while the effects of those of a muscle of voluntary motion, or even an organ of sense, although often a part of greater sensibility, is confined to the injured part? If the eye or ear, or the muscle of a limb, be so deranged by a sudden blow, for example, as instantly to destroy its power, sight, hearing, or the voluntary power of the part is lost, and there the evil ends unless inflammation ensues; but a blow on the stomach, which instantly destroys its power, at the same moment destroys that of every other part. It is not difficult to answer the question, since the

state of the stomach, from the cause just pointed out, may influence every part of the nervous system; and it appears from experiments which the Society did me the honour to publish many years ago, some of which were repeated by Mr. Cliff, that a powerful and sudden affection of the nervous system is capable of immediately destroying the circulation in every part of the animal, by instantly depriving both the heart and blood-vessels of their power.

Here the question naturally arises. For what purpose are the vital organs thus connected with every part of the brain and spinal marrow?

This question is answered by experiments detailed in my treatise on the Vital Functions, an account of some of which appeared in the Philosophical Transactions of 1822. From them it was found that the power of secreting surfaces is deranged by abstracting from them any considerable part of the influence either of the brain or spinal marrow; and as the function of secretion is effected by the action of the nerves on the blood, as appears from facts detailed in the paper just referred to, and another which I had the honour to lay before the Society a few weeks ago, it is evident that the presence of nervous power in a secreting organ would be useless, were not the blood on which it operates also supplied, and disordered if it were not supplied in due proportion; and consequently its supply varied as the supply of nervous power varies.

We thus see not only why secreting surfaces are placed under the influence of every part of the nervous system, but also why it is necessary that the sanguiferous system should be under the controul of the same laws which regulate the supply of nervous power.

It appears then that by means of the system of ganglionic nerves, the influence of every part of the brain and spinal marrow is bestowed on secreting surfaces, and on those organs by which the supply of their fluids is regulated, and that this influence is necessary to their functions. But it is not the secreting power alone that is thus placed under the influence of every part of the brain and spinal marrow; for it is a necessary inference from experiments related in a paper which the Society did me the honour to publish last year, that the whole of those processes on which the healthy structure of the part depends are under the same influence.

The influence therefore of the whole brain and spinal marrow is thus united by nerves from various parts of these organs entering ganglions and plexuses,

from which are sent to every part of the body nerves proved by direct experiment to convey the influence of every part of them; and this combined influence of the brain and spinal marrow is employed in forming the various secreted fluids, and supporting the other processes on which the due structure of every part depends; and I have in a treatise entitled "On Indigestion" pointed out how extensively the phenomena and treatment of all diseases are influenced by this cause.

Such then is the relation which subsists between the nervous system and the other vital organs I have had occasion to mention; but there is another relation of that system which must be considered before the nature of its functions can be clearly understood.

The nervous system, in the usual acceptation of the term, is very ill defined, and functions of the most dissimilar nature are classed together under the general denomination of nervous. Those of sensation and volition, for example, are classed with the excitement of a muscle and the formation of a secreted fluid. It seems highly improbable that results so different should arise from the same or similar causes. On the most cursory view of the subject, we cannot help supposing that the nervous system, according to the common acceptation of the term, includes more than one principle of action. We have every reason to believe, that the sensorial is a power wholly distinct from that strictly called nervous; and all doubt seems to be removed by the circumstance, that although the organs of both belong to the nervous system, it is evident they are not the same organs, because the sensorial power resides chiefly in the brain while the nervous power, properly so called, resides equally in the brain and spinal marrow; the latter of which organs is capable of its functions independently of the former, as appears from many of the experiments of Le Gallois, which have been confirmed by several of my own.

It occurred to me on reviewing the whole of these circumstances, that as we can destroy the nervous, without at all impairing the muscular power, it might be possible to remove the sensorial power without immediately destroying that more strictly called nervous.

I made many experiments, which are detailed in my treatise on the Vital Functions, for the purpose of determining this point; from which it appears that in all modes of death, except the most sudden, (arising from a violent and

sudden impression made on the nervous system, by which the whole of the functions are instantaneously destroyed,) the sensorial functions are the first which cease, all the other powers of the system remaining more or less perfect, and any imperfection which appears in them not directly depending on the loss of the sensorial power.

Of the sensorial functions, sensation and volition are the only ones which we are called upon to consider here, because they alone have any share in maintaining animal life. That these functions are essential to the maintenance of life in all the more perfect animals, will, I think, appear from what I am about to lay before the Society.

The following may be regarded as the nervous functions properly so called. The excitement of the muscles of voluntary motion, by which through the intervention of the nervous system, they in their usual functions are subjected to the sensorial power; the occasional excitement of the muscles of involuntary motion, by which under certain circumstances the sensorial power is also capable of impressing them through the nerves, particularly when under the influence of the passions; the act of causing an evolution of caloric from the blood, by which the due temperature of the animal body is maintained; the act of forming from the blood the various secreted fluids, and of maintaining the other assimilating processes by which the healthy structure of every part of the body is preserved.

The first of these functions is universally acknowledged to be a function of the nervous power, properly so called; but there has been much difference of opinion respecting the way in which it operates. The older physiologists believed that the muscles derive their power from the nervous system. Haller* was the first who taught that the muscular power belongs to the muscle itself, to which the nervous power bears no relation but that of a stimulus, and endeavoured to support those opinions by experiment. His opponents, however, objected to his inferences, because, although the division of the nerves may prevent the muscle from receiving more nervous power, it does not deprive it of that already bestowed upon it, either existing in the muscular fibres themselves, or dispersed through them in nerves too small to be removed; and this objection appeared to be strengthened by the muscles of involuntary motion,

* Element. Physiolog.

whose function is supported by stimuli peculiar to themselves, being still supplied with nerves, of the use of which HALLER gave no satisfactory account. It appeared to me that the question could only be determined by some experiment capable of directly ascertaining whether the excitability of muscles is maintained by the influence they receive from the nerves, or impaired as by other stimuli. On trial, the latter was found to be the case. Muscles whose nerves had been divided, sustained the action of the same stimulus longer than those whose nerves were entire, and which consequently were exposed to the action both of the nervous power applied by the will of the animal and the artificial stimulus*. The power of the muscle, therefore, is independent of the nervous power, and is affected by it in the same way as by other stimuli.

The experiments by which all the other functions just mentioned, with the exception of the maintenance of animal temperature, have been ascertained to be functions of the nervous power, I have laid before the Society, which has done me the honour to publish them. From these experiments it appeared that the functions in question were always destroyed by depriving their organs of the influence of the nervous system. That the maintenance of animal temperature is a function of the nervous system, properly so called, appears from a variety of facts generally known, the temperature either of a part or of the whole body being lessened by any cause that impairs the action of particular nerves in the former instance, or of the whole nervous system in the latter. The question then is, is the nervous system capable of all these functions after the sensorial power is withdrawn?

At the moment of what we call death, the sensorial functions cease, the animal no longer feels or wills. Whether the nervous functions properly so called still continue, can only be determined by experiment. That the nerves when stimulated are still capable of exciting the muscles of voluntary motion is a fact generally admitted; and that they are still capable of exciting the action of the muscles of involuntary motion, appears from many experiments related in the second paper, which I had the honour to present to the Society, and which was published in the Philosophical Transactions of 1815. That the nervous system is capable of causing the evolution of caloric, which supports animal temperature after the sensorial power is withdrawn, appears

* My Treatise on the Vital Functions, third edition, Exper. 34, 35.

from many experiments related in my treatise on the Vital Functions; and that the nervous power under the same circumstances is still capable of forming the secreted fluids, and supporting the other processes by which the structure of every part is maintained, is shown by very frequently repeated experiments on the newly dead animal related in the same treatise. From these experiments it appears that some secretion of gastric juice takes place after what we call death, and that some derangement of structure in the lungs may be produced by dividing the eighth pair of nerves immediately after death; a proof that the processes on which the structure of the part depends, continue for some time after the sensorial power can no longer influence them.

We may thus trace the existence of the whole of the nervous functions properly so called after the removal of the sensorial power. The former therefore have no immediate dependence on the latter; but in the entire animal we know that the nervous, in many of its functions always, and occasionally in all of them, is subjected to the sensorial, power. These powers therefore bear the same relation to each other that the nervous and muscular powers do, the muscular existing independently of the nervous, but being influenced by it.

It was this independence of the functions properly called nervous on those of the sensorial power, and the analogy which subsists between the former and chemical processes, which suggested that the agent, on which the nervous functions immediately depend, instead of being peculiar to the living animal, may only be an agent employed by those powers which are so, in the same way as any other constituent part which the living animal possesses in common with inanimate nature; and it appeared to me that the accuracy of this suggestion would be placed beyond a doubt if the nervous power could be proved to be capable of its function, after it had been made to pass through any other conductor than the nerves; for it will be admitted that the powers peculiar to the living animal can only operate, and, as far as we see, can only exist in the organs to which they belong. The brain cannot perform the office of a muscle, nor a muscle that of the brain.

If then the nervous power can be made to pass through any substance but that of the nervous system in which it resides, it evidently has an existence independent of the mechanism of that system, and therefore is not peculiar to it. This, after many vain attempts, I succeeded in effecting. It appears from ex-

periments, an account of which the Society did me the honour to publish in 1822, and which have been repeated with the same result by M. Brechet and other physiologists at Paris, that the nervous power is capable of its function after it has been made to pass through other conductors than the nerves.

It would seem, therefore, that however generally the nervous power has been confounded with those powers more strictly called vital, it is only an agent employed by them. This view of the subject seemed to point out the possibility of finding some of those powers which operate in inanimate nature capable of the functions of the nervous power properly so called, if brought to operate under the same circumstances; and on trial it was found, as appears from experiments published in the Philosophical Transactions of 1822 and 1828, and repeated with the same result by Dr. Abel*, M. Brechet† and others, that galvanism may be substituted for the nervous power, not only in the more simple, but in the more complicated functions of that power. It not only appears that galvanism is capable of exciting the muscles and causing an evolution of caloric from arterial blood‡, but of forming the secreted fluids from the blood, and supporting all those functions on which the structure of the body depends. How far do the whole of these facts, whether relating to the nature or functions of the nervous power, go in proving its identity with galvanism?

On reviewing what has been said of the relations of the sensorial, nervous, and muscular powers, the question naturally arises; If both the nervous and muscular powers are thus independent of the sensorial power, and capable of their functions after it is withdrawn, why do the more perfect animals for so short a time survive the loss of the sensorial functions? The cause is, that on the removal of the sensorial power, respiration ceases; because this function partakes of all the three powers, the sensorial, nervous, and muscular.

It has been customary to speak of the muscles of respiration as at least in part muscles of involuntary motion. What is meant by a muscle of voluntary

* The London Medical and Physical Journal for May 1820, vol. xliii. p. 385.

† De l'Influence du Système Nerveux sur la Digestion Stomacale; par MM. Breschet, D.M.P., chef de Travaux Anatomiques de la Faculté de Medecine de Paris, etc.; H. Milne Edwards, D.M.P.; et Vavasseur, D.M.P. (Mémoire lu à la Société Philomatic la 2 Aout, 1823.) Extrait des *Archives Generales de Medecine*, Aout 1823.

‡ My Treatise on the Vital Functions, third edition, Exper. 80, 81, 82, 83, 84, 85, 86.

motion? It is a muscle whose action under all ordinary circumstances we can excite, interrupt, retard, and accelerate at pleasure, but it is not a muscle whose action we can at all times controul. There is no such muscle, because the impression on the sensorium tending to call any particular set of muscles into action may be so powerful, that we are unable to controul it. Who can prevent the action of the muscles of the arm when fire is suddenly applied to the fingers? Neither do we mean by the term muscle of voluntary motion, one which we cannot call into action during sleep. If our posture during sleep becomes uncomfortable, we call the muscles both of the trunk and limbs into action for the purpose of changing it. The uneasiness caused by the continuance of the same posture, sufficiently rouses the sleeper to make him will a change of posture, without rendering him at all more sensible to other impressions of a slighter nature, and his sleep continues.

What muscles then are more under command than those of respiration? We can on all usual occasions interrupt, renew, retard, or accelerate their action at pleasure; and if we cannot interrupt it for as long a time as that of the muscles of a limb, this depends on no peculiarity in the action of these muscles, but on the nature of the office they are called on to perform; and if we excite them in sleep for the removal of an uneasy sensation, and cannot controul them under a sense of suffocation, that is, in a state of greater suffering than we can voluntarily bear, all this is no more than applies to every other muscle of voluntary motion: but from the nature of our constitution we must breathe many times every minute, and we need not turn ourselves more than once in many hours,—a difference depending on circumstances which have nothing to do with the nature of the muscles we employ in either of these acts.

If we find the breathing going on in apoplexy after all voluntary motion of the limbs has ceased, it is because the sensation exists which calls on the patient to inflate his lungs, while there is none which calls for the action of the limbs. In the slighter states of apoplexy if the limbs be much irritated, the muscles which move them will also be called into action; and in the severer states, if the patient breathes, when no irritation of the limbs can excite him to move them, it is that the want of wholesome air in the lungs, after a certain interval, produces a more powerful impression than any other means we can employ. People have voluntarily held the hand in the fire, but no man ever

voluntarily abstained from breathing till the lungs were injured. When at length no irritation, however violent, can impress the sensorium, the breathing ceases and death ensues. The mode of death sufficiently illustrates what is here said. We find the intervals of breathing becoming longer before it ceases. As the insensibility increases, a greater want of fresh air is necessary to excite the patient to inspire, till at length the total privation of fresh air no longer producing any sensation, can no longer excite this effort.

The muscles of respiration then, it would appear, are as perfectly muscles of voluntary motion as those of the limbs, and are never excited but by an act of the sensorium. When there is no feeling to induce us to breathe, the breathing ceases.

That on ordinary occasions we are unconscious of this feeling, in the common acceptation of the term, (that is, that it makes no lasting impression on the mind, for this is necessary to what we mean by consciousness,) unless the attention is particularly directed to it, is no proof that it has not existed. When we direct our attention to the act of breathing, especially if we breathe more slowly than usual, we can distinctly perceive the sensation which induces us to inspire, and that it is a voluntary act which relieves it.

The same observations respecting consciousness apply to all the more trivial habitual acts of the sensorium. In playing on an instrument, we cannot tell which finger last struck the chord; in walking, we cannot tell which leg we last moved;—yet all such acts are strictly acts of volition: when we attend to them we can regulate them as we please, but in proportion as they are habitual we attend to them the less, and therefore least of all to the act of respiration.

To the consciousness of having experienced any feeling, it is evident that its strength, or some other circumstance attending it, must be such as to impress it on the memory. We are every hour performing many acts of volition which are too trivial to be remembered, and consequently at the time we are questioned we have no consciousness of their having existed. The proper feeling excites the act required, but the feeling is too habitual to command the attention.

It may be difficult for a person not accustomed to reflect on such subjects, to believe that every time his leg is moved in walking, he performs a distinct act of volition; but he will be convinced of this if he observes the motions of

those whose power of volition is impaired by disease. He will find the patient hesitate which leg to move at every step, and at length his attempts to move the limbs produce a confused and irregular action incapable of carrying him forward.

The act of expanding the chest is an act of volition, it is an act in ordinary breathing rendered extremely easy by the gentleness of the motion required, and the continual habit which renders it familiar, and is excited by a sensation proportionably slight, but which is as essential to it as stronger sensations are to more powerful acts of volition. Thus it is that on the removal of the sensorial power respiration ceases. It may be here said perhaps, that we have no instance of a muscle of voluntary motion continuing to act at short intervals during life; but besides that this is begging the question, it is to be recollected that the action of the muscles in ordinary respiration is very slight, and performed at considerable intervals, for it is only during inspiration that the muscles act. They are quiescent during expiration, which in our usual breathing is performed by the elasticity of the cartilages and the weight of the parts concerned. There is perhaps no muscle of the body which could not without fatigue maintain a similar action were there a cause capable of exciting it. In certain diseases we find both more powerful and more frequent actions of the muscles of volition continued for years during the whole of our waking hours without any complaint of fatigue.

When the change in the blood, effected by respiration, no longer takes place, most of the pulmonary vessels lose their proper stimulus, red blood; and feel more directly perhaps the debilitating influence of black blood; their functions therefore begin to fail. In proportion as this happens, the blood accumulates in the lungs. The right side of the heart consequently experiences an increased difficulty in emptying itself, and the due supply of blood to the left side fails. By the operation of these causes both sides of the heart, particularly in warm-blooded animals, soon lose their power after respiration ceases. The arteries under such circumstances, it is evident, cannot long supply fluids proper for the purposes of assimilation. The nervous and muscular solids therefore deviate from the state necessary for the functions of life, which at length cease in every part.

The foregoing appears to be the order in which the functions always, with

the exception of their instantaneous destruction as above mentioned, cease in death; whether it be occasioned by injury of the sanguiferous or nervous system, or both.

Such then appears to be the nature of respiration. The first act is the impression made on the sensorium, the sensation excited by the want of fresh air in the lungs. We are enabled to supply it, and thus remove the uneasiness, by exciting certain muscles subjected to the will. Through nerves which are fitted for this purpose, we apply a stimulus to certain muscles which perform the act required. Thus respiration is the combined act of the sensorial nervous and muscular powers. It is as effectually destroyed by a failure of the sensation which makes us will to inspire, as by that of the nervous or muscular power by which the will effects its object. With this view of the subject before us, and I can see no other which the facts admit of, it will be proper to examine the nature of respiration more in detail.

I have already had occasion to observe, that the effort made in ordinary breathing is very slight. It is chiefly performed by the diaphragm, by the contraction of which the cavity of the chest being slightly enlarged perpendicularly, the pressure of the atmosphere readily causes the air cells to be distended with air; but if any obstacle occurs tending to prevent the passage of the air to the cells, a greater effort is required, and other muscles are called into action. It seems almost unnecessary to observe, that the sensation which induces us to make this greater effort, must, as the object is still the same, operate in the same way. The more powerful sensation indeed, and the trouble the effort gives us, by calling our attention to it, enables us at once to perceive that it is an effort of the same kind with any other voluntary effort by which we endeavour to relieve ourselves from a painful feeling, and, like any other powerful voluntary effort long continued, produces the feelings of fatigue. Would any privation of air induce the struggle that we see in severe dyspnœa, if no sensation were excited by it? This sensation is excited in the sensorium through the nerves of the lungs, and all that follows is evidently the result of it.

The effort consists in two things, drawing the air into the chest with greater force, that is, expanding the chest more forcibly that the air may enter it with a greater degree of atmospheric pressure, and thus any obstacle to its entrance be overcome; and doing all we can to enlarge the passage by which the air enters.

The action of the muscles by which these objects are effected has been ascribed to a particular sympathy supposed to exist between certain nerves. But if the eighth pair of nerves which supplies the lungs originate near the nerves of the diaphragm, and certain muscles of the face, by which the nostrils are expanded, this cannot be said of the nerves of many other muscles equally called into action in severe dyspnœa, the muscles of the loins, &c.; and if we could by what is called sympathy of nerves explain the phenomena in question, it is not to be overlooked that the same sympathy must exist with respect to the abdominal as thoracic viscera, for the same nerves supply both.

We must therefore look for another principle to account for the relation which subsists between such acts and peculiar states of the lungs. The principle is at hand. The sensation which induces us to inspire forms a necessary link in the chain of causes; for every contraction excited in the muscles is evidently calculated to relieve this sensation in one of the two ways just pointed out. It either tends to expand the chest, or enlarge the passage of the air. It is impossible in such a case to overlook the act of the sensorium, which is sufficient to account for the phenomena without any particular sympathy of nerves, which on the other hand, I have just had occasion to point out, is insufficient for this purpose.

The muscles employed in extreme dyspnœa are not confined to a particular set. They are the whole muscles of the trunk, and sometimes many of the limbs also, muscles which have nothing in common, except that they are all muscles of voluntary motion, and bear the same relation to the nervous and sensorial systems which all other muscles of voluntary motion do. Actions of the muscles of the face indeed are equally associated with sensations referred to the abdomen and the limbs, and arising from causes operating in them. Who can have a placid countenance while in agony from the operation of any cause to whatever part applied?

It appears from a great variety of experiments to which I have referred, that organs supplied with ganglionic nerves are subjected to the influence not of any one, but of every part of the brain and spinal marrow. No inference therefore can be drawn respecting the sympathies of any ganglionic nerve, as the term is here used, that is a nerve that either enters or proceeds from ganglions, according to the sense in which I use the term, from any particular distribution of nerves, or from the part where any particular nerve which con-

tributes to the power of the ganglionic system originates. Vital organs are equally connected with every part of the brain and spinal marrow; and if we must not look for those partial sympathies with respect to their other functions, there is still less room, it is evident, to look for them in those functions where the sensorial power is concerned.

The sensorium evidently residing and operating at the source of nervous power, there receives the various impressions conveyed by the nerves, and there influences those nerves which convey its dictates.

I shall beg leave to conclude this paper with a short recapitulation of the principal points which appear to be ascertained by the experiments referred to in it.

The nerves are divided into two classes, whose functions essentially differ; those proceeding directly from the brain and spinal marrow, which, in the one direction, convey the influence of the parts of those organs from which they have their origin, and are the sole means of exciting the muscles of voluntary motion; and in the other, impressions which influence the sensorium: and the ganglionic nerves, which, while they also convey impressions to the sensorium and occasionally excite the muscles of involuntary motion, usually excited by stimuli peculiar to themselves, have for their principal function one of greater importance, and which requires the combined influence of the whole brain and spinal marrow, that of supporting the various processes of secretion and assimilation, and are consequently in the strictest sense a vital organ.

Although the nervous power therefore stands only in the relation of a stimulus to the muscular fibre, whether of voluntary or involuntary motion, in no degree contributing to its power, which depends on its own mechanism; it is essential to the existence of the secreting and assimilating powers, which are immediately destroyed by withdrawing its influence.

Such is the relation which the nervous system bears to what may be termed the circumference of the animal body, in contradistinction to the sensorium, which may be justly regarded as its centre, to which that system bears a relation of equal importance; for it may be regarded as the means of connecting the organs of the sensorium with all other parts. In its power this system is independent of the sensorium, for we have seen it capable of all its functions after the sensorial power is withdrawn; but in all of them it is in-

fluenced by it, constantly in some, occasionally in others. It therefore bears the same relation to the sensorial organs which the muscles bear to it. As the muscular is independent of the nervous power, so is the nervous of the sensorial power. As the nervous, influence all the muscular, functions, those of the muscles of voluntary motion constantly, those of the muscles of involuntary motion occasionally; so the sensorial, influence all the nervous, functions, those of the cerebral and spinal nerves constantly, those of the ganglionic nerves occasionally. Thus all the functions of the nervous and muscular systems, by which we are connected with the world that surrounds us, are constantly subjected to the sensorial power; while the functions on which our life depends, with the exception of respiration, are only occasionally so, and under circumstances in which the will has no controul. With this exception the latter are all functions of the nervous and muscular powers alone. To respiration the sensorial power also is necessary, and therefore the nervous and muscular powers never long survive the loss of the sensorial power.

The nervous power which connects all the other powers of the animal body, effects so many changes in it, and has so large a share in connecting it with the world around it, cannot strictly speaking be regarded as one of the vital powers of that body, but as an agent employed by those powers; because it has been proved by direct experiment that it is capable of existing independently of the mechanism of the part in which it resides, and therefore is not peculiar to that mechanism; and by the same means, that all its functions may be performed by galvanism, made to operate in the same circumstances in which the nervous power operates.

The experiments referred to in the foregoing paper suggested the use of galvanism in those diseases which arise either from a partial or general failure of the nervous power; and the success which has attended its employment has afforded another proof of its capability of the functions of that power. The diseases in which it has been chiefly employed are habitual asthma, the various forms of indigestion, affections of the spinal marrow and general nervous debility. An account of its effects in the first of these diseases was laid before the Society, and published in the Philosophical Transactions of 1817. An account of its effects in the others is published in the third edition of my treatise on the Vital Functions.